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Ho et al.

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(54) **PACKAGING SUBSTRATE WITHOUT PLATING BAR AND A METHOD OF FORMING THE SAME**

(58) **Field of Classification Search** 438/584;
29/592.1, 825, 829, 846
See application file for complete search history.

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

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(21) Appl. No.: **10/945,961**

(57) **ABSTRACT**

(22) Filed: **Sep. 22, 2004**

A packaging substrate without plating bar and a method of forming the same is provided. A substrate is firstly provided with circuit patterns formed thereon. Then, solder masks are formed to define connecting points on the circuit patterns. Afterward, the openings of the solder mask on a bottom surface of the substrate are filled with solder material. Thereafter, a seed layer is formed on the bottom surface of the solder mask and the solder material, and then a passivation layer is formed on a surface of the seed layer. Finally, a plating process is carried out by using the seed layer to input cathode electric level to form metal pads on the defined connecting points on the upper surface of the substrate.

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(30) **Foreign Application Priority Data**

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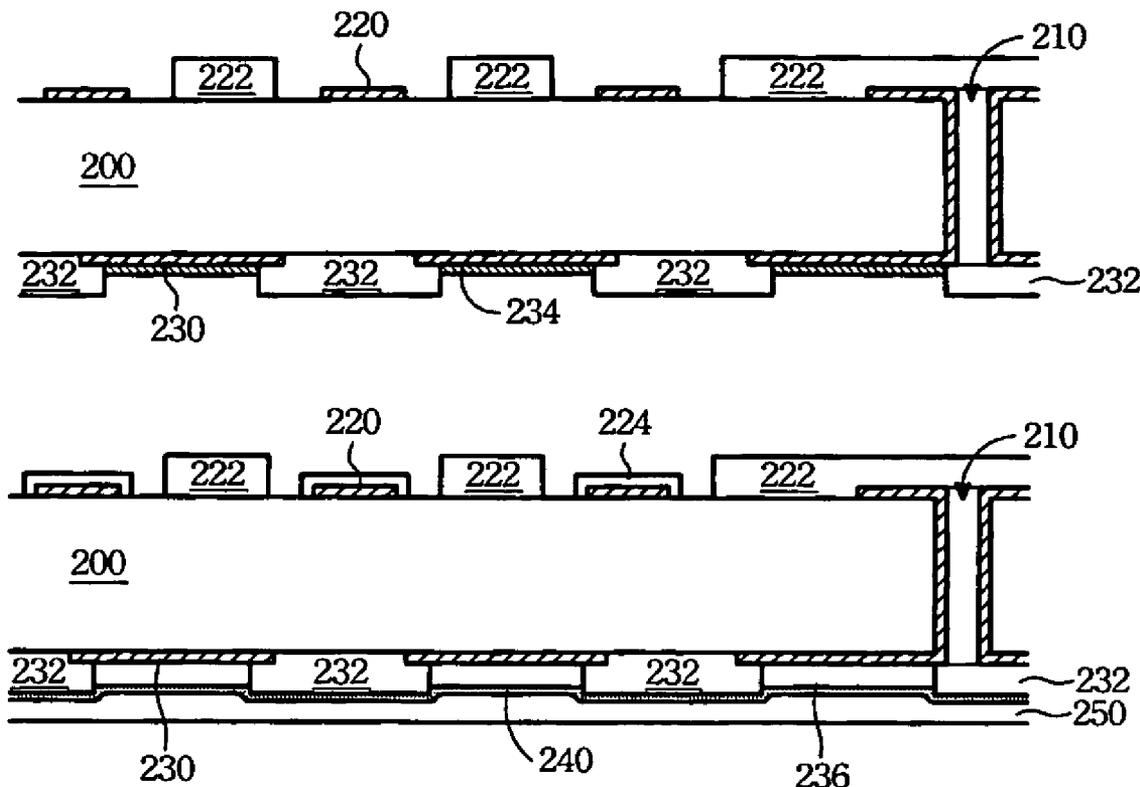
(51) **Int. Cl.**

H01L 21/20 (2006.01)

H05K 3/00 (2006.01)

(52) **U.S. Cl.** 438/584; 29/829

12 Claims, 9 Drawing Sheets



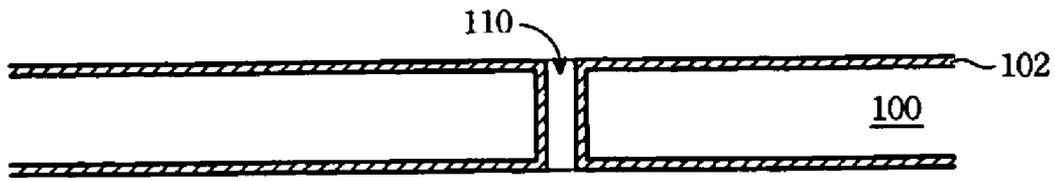


FIG. 1 A (Prior Art)

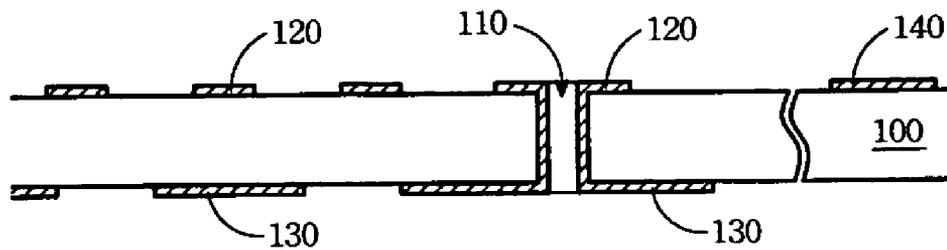


FIG. 1 B (Prior Art)

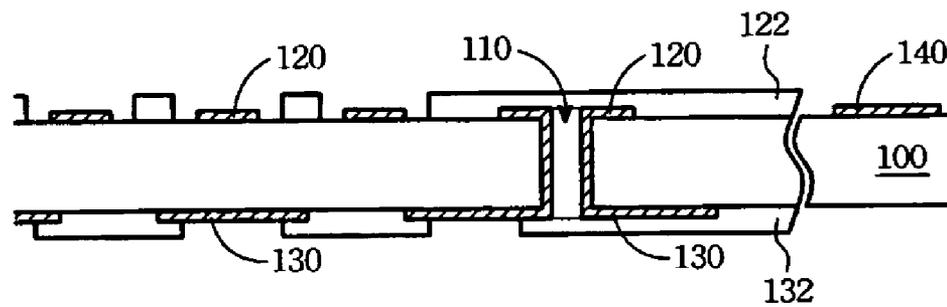


FIG. 1 C (Prior Art)

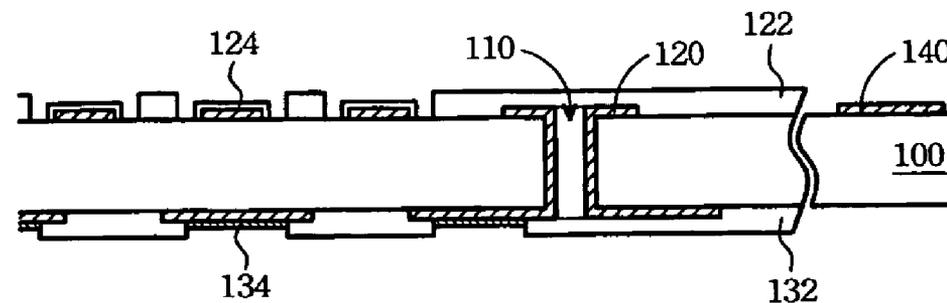


FIG. 1 D (Prior Art)

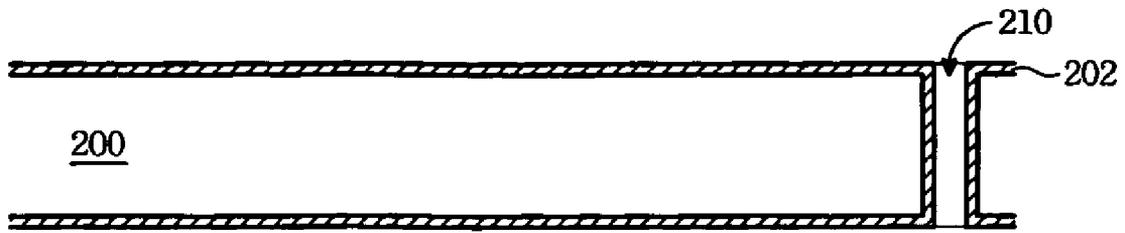


FIG. 2A

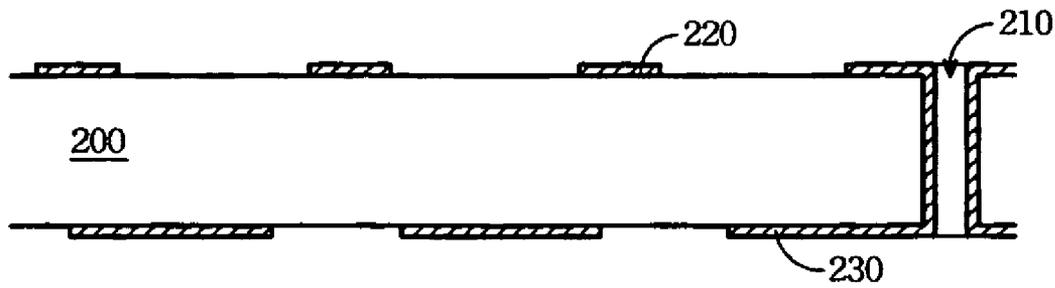


FIG. 2B

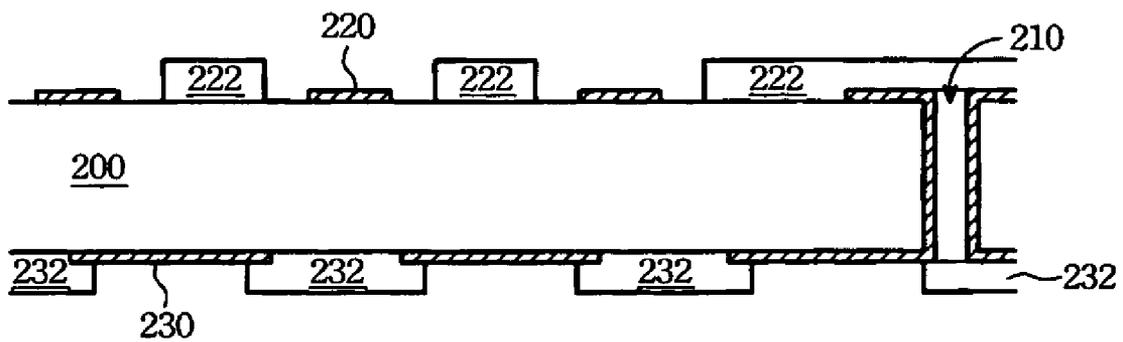


FIG. 2C

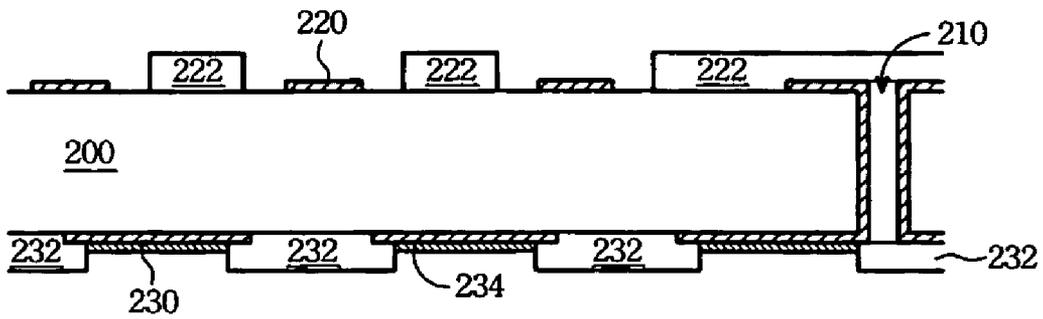


FIG. 2D

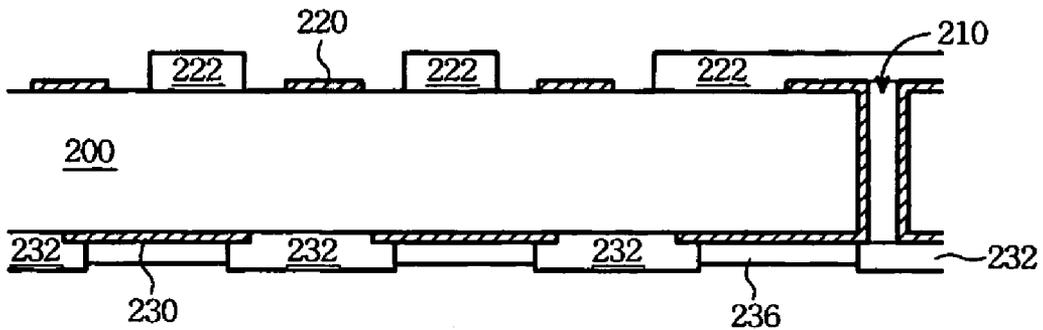


FIG. 2E

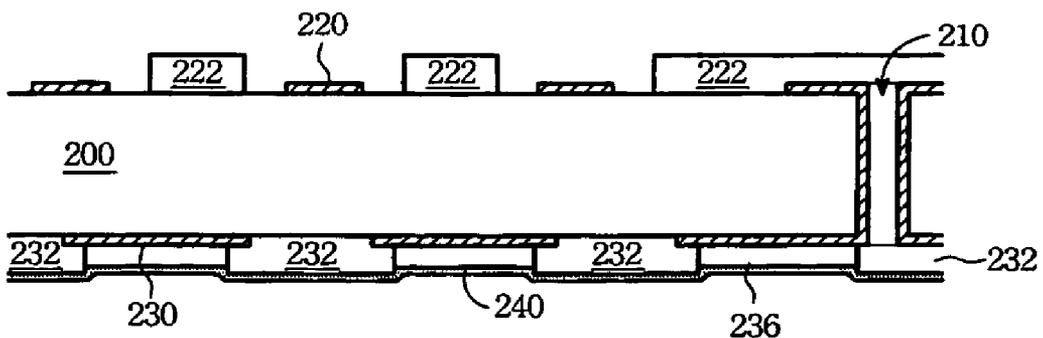


FIG. 2F

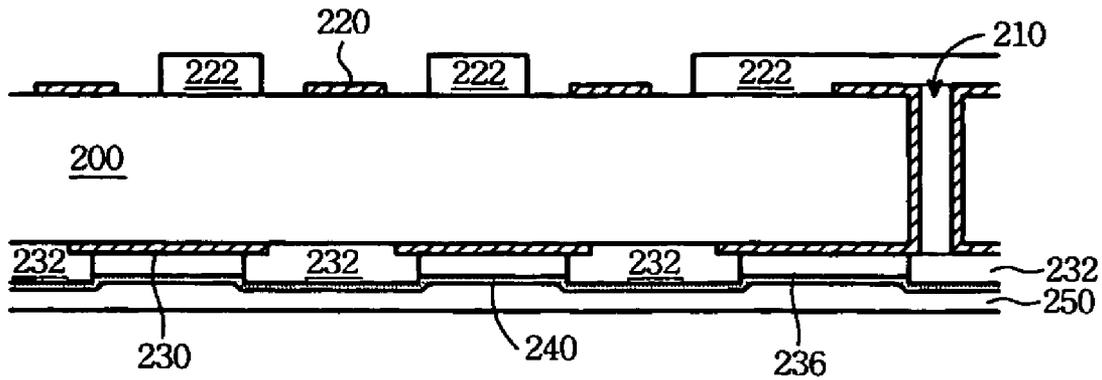


FIG. 2G

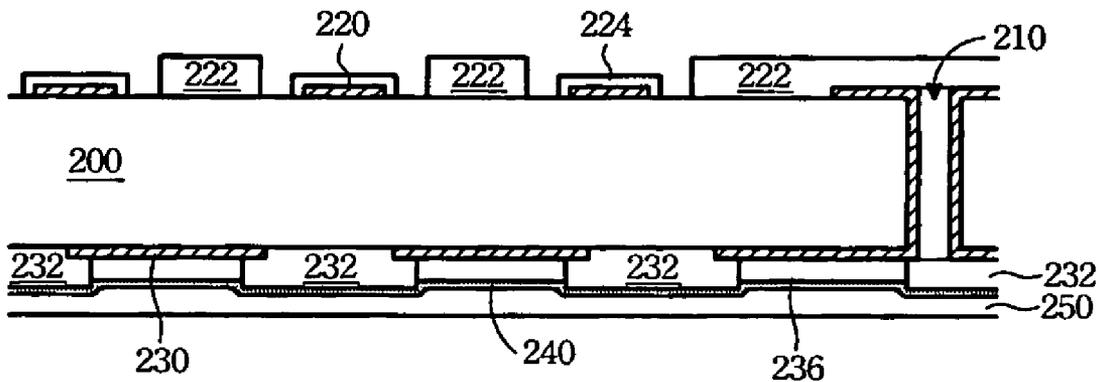


FIG. 2H

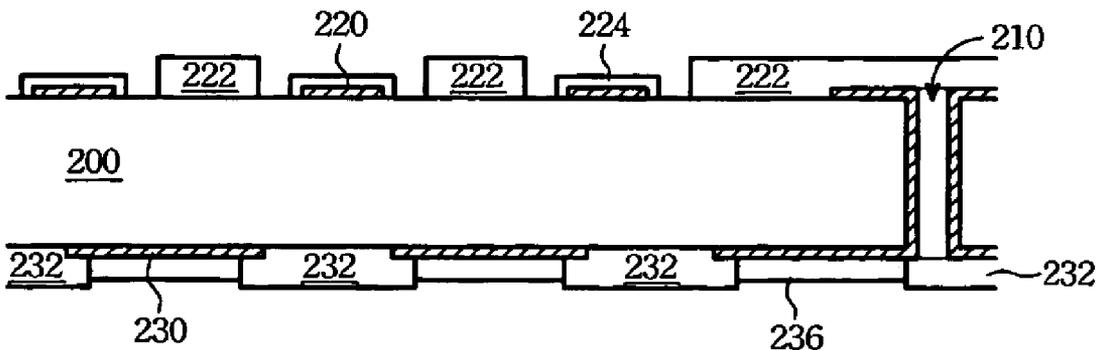


FIG. 2I

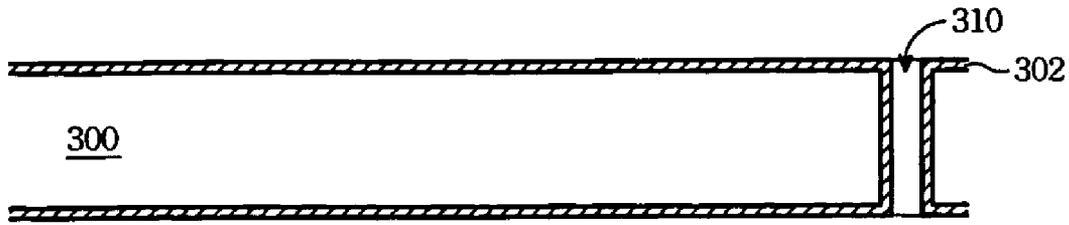


FIG. 3A

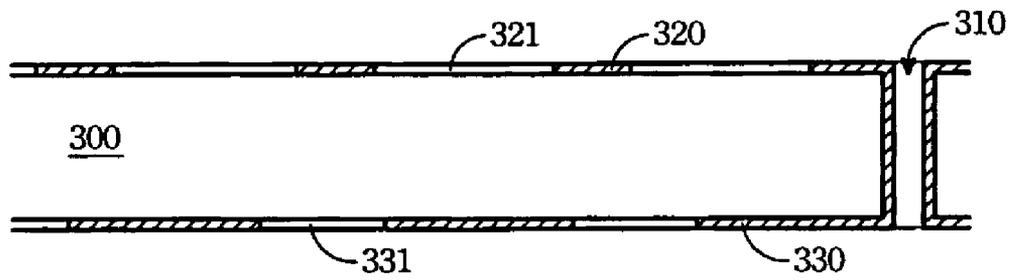


FIG. 3B

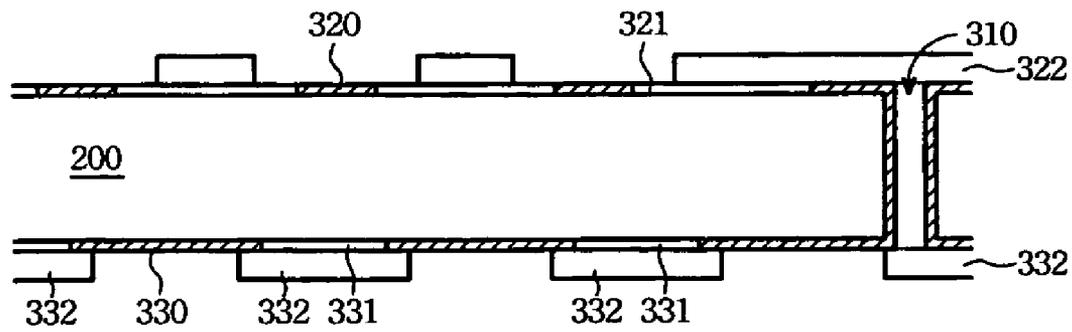


FIG. 3C

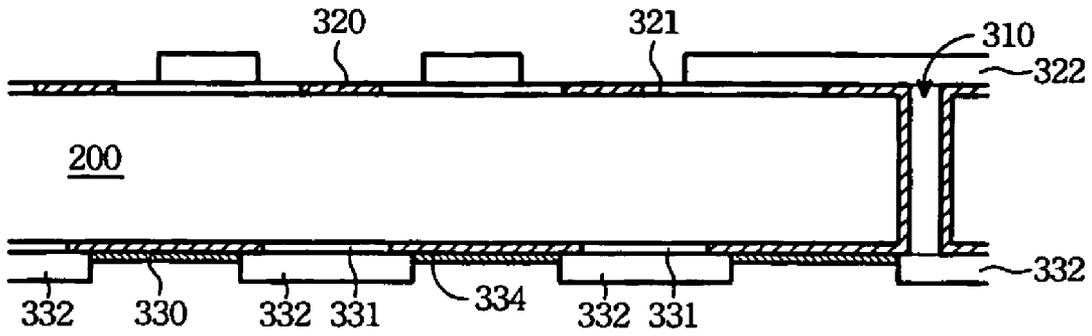


FIG. 3D

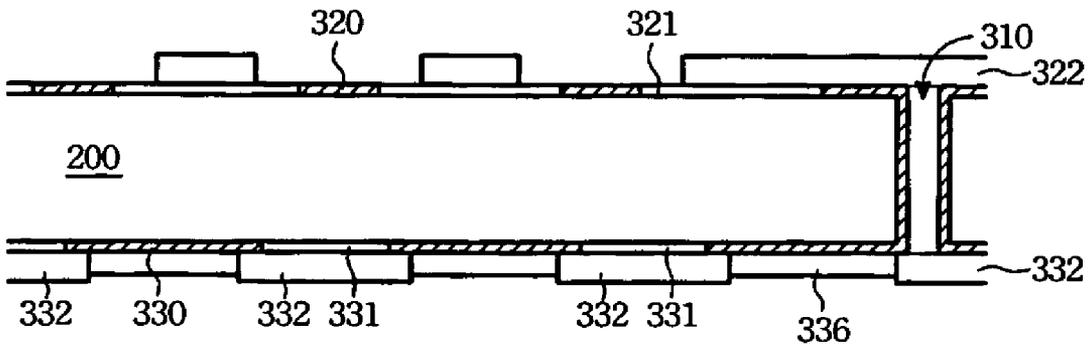


FIG. 3E

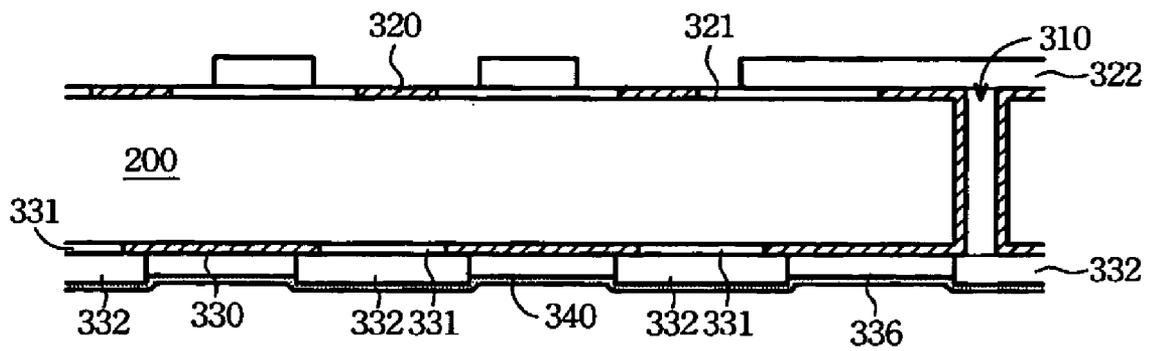


FIG. 3F

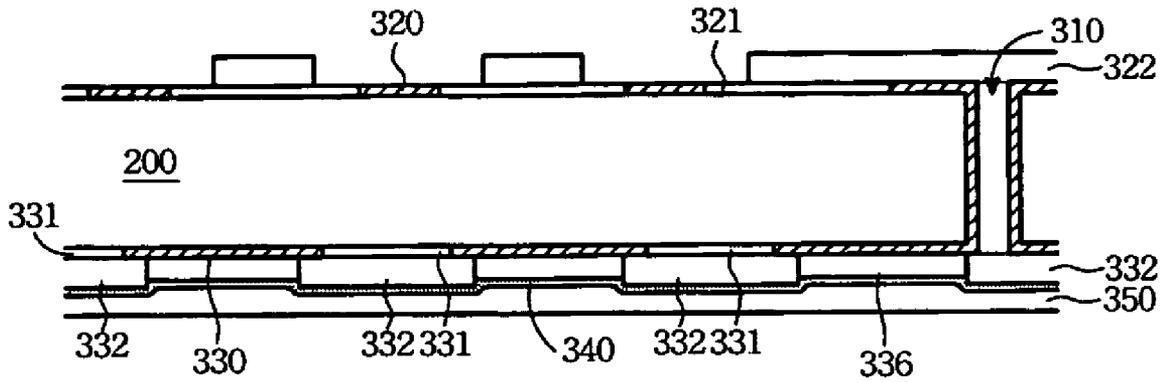


FIG. 3G

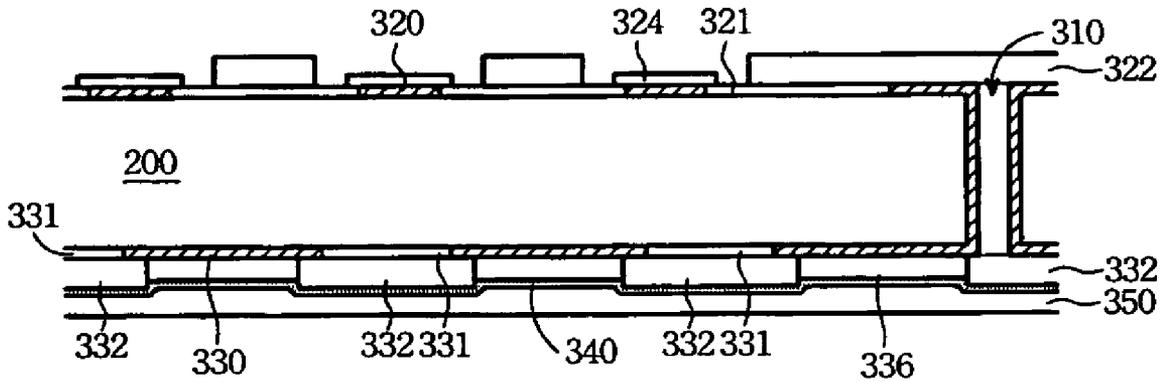


FIG. 3H

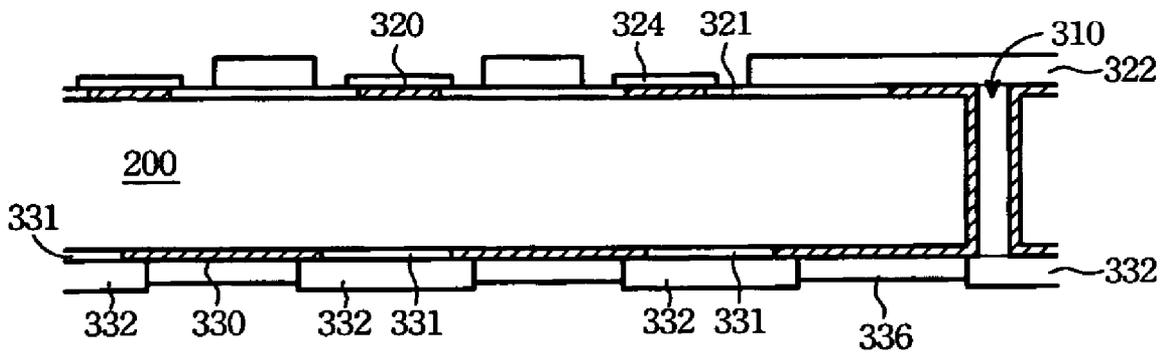


FIG. 3I

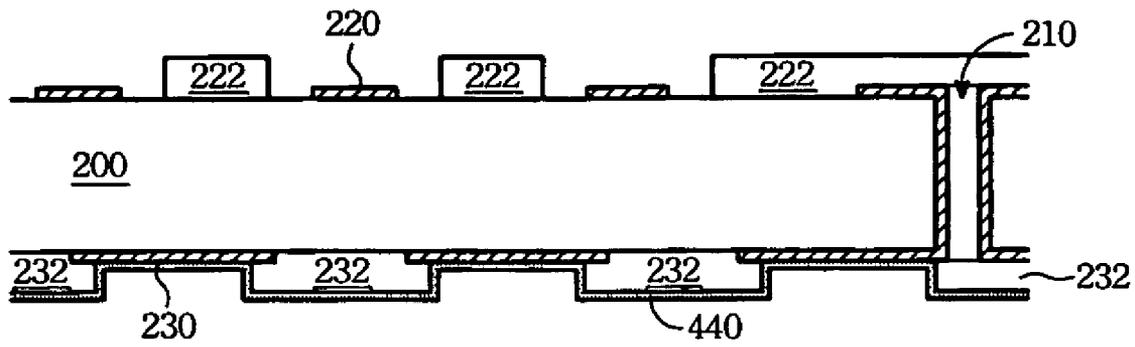


FIG. 4A

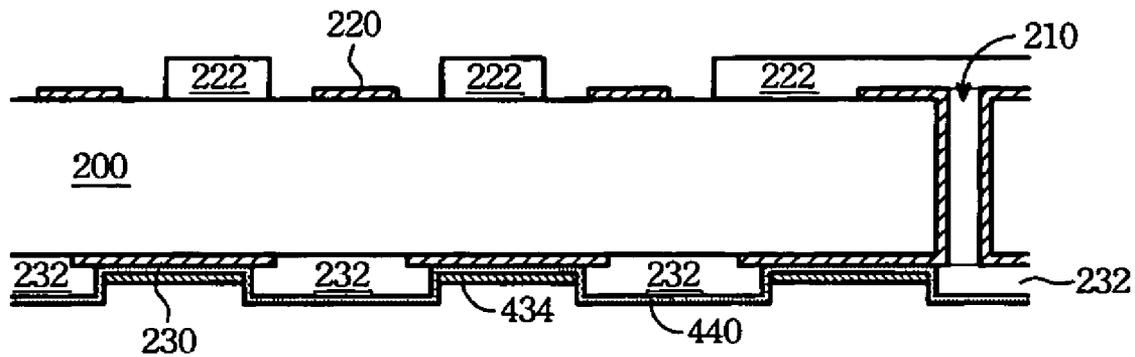


FIG. 4B

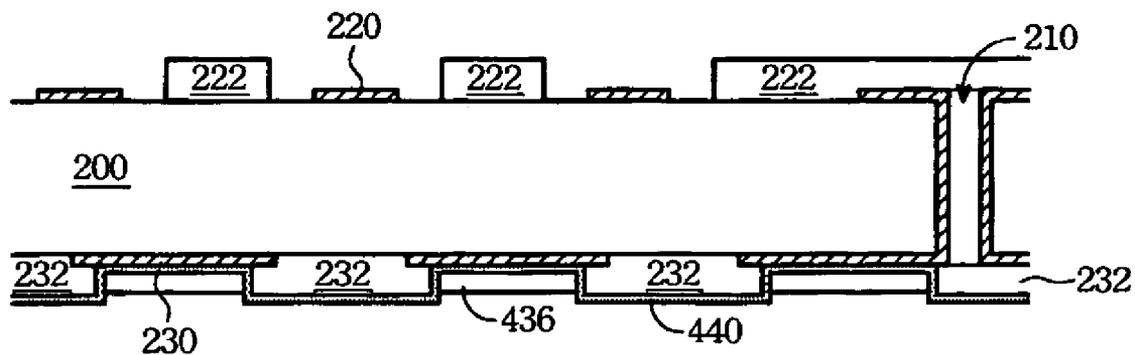


FIG. 4C

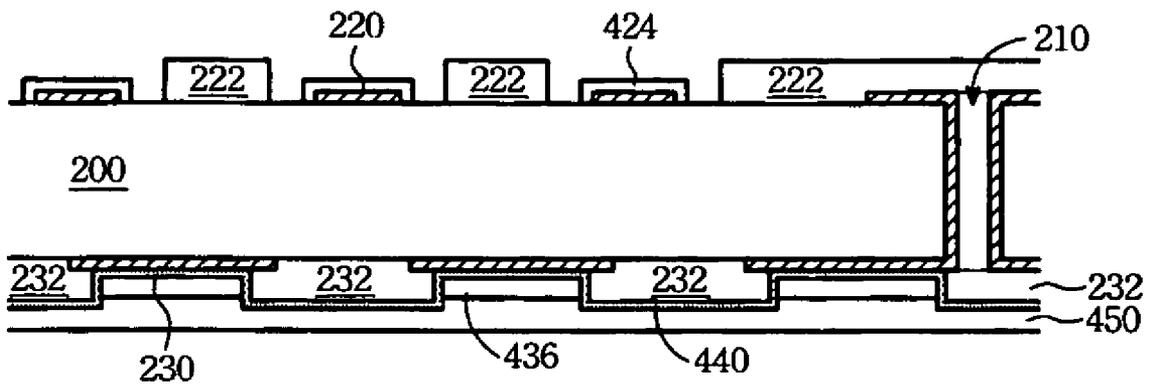


FIG. 4D

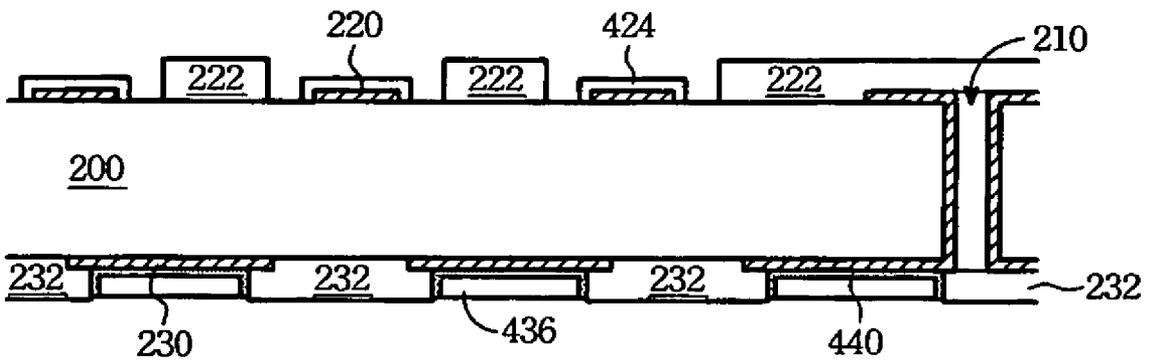


FIG. 4E

**PACKAGING SUBSTRATE WITHOUT
PLATING BAR AND A METHOD OF
FORMING THE SAME**

BACKGROUND OF THE INVENTION

(1) Field of the Invention

This invention relates to a packaging substrate and a method of forming the same, and more particularly to a packaging substrate without a plating bar.

(2) Description of Related Art

As semiconductor fabrication technology has been effectively improving, it is the trend to have a central processing unit (CPU) characterized with small-size, multi-function, and high-speed. Such a CPU needs an increased number of input/output (I/O) contacts to transmit data for various purposes, and is usually formed with arrayed I/O pads to increase I/O density (pitch $\leq 200 \mu\text{m}$). To deal with the arrayed I/O pads, a flip-chip packaging method, in which a die is connected to a packaging substrate by using bumps, becomes more popular.

FIGS. 1A to 1D depict schematic cross-section views of a fabrication method of a packaging substrate for flip-chip packaging. Firstly, as shown in FIG. 1A, a substrate **100** is provided with through holes **110** formed by mechanical or laser drilling. Afterward, the through holes **110** are plated with conductive material, and then conductive layers **102** connecting to the plated through holes **110** are formed on opposing surfaces of the substrate **100**. Then, as shown in FIG. 1B, a lithographic and etching process is carried out toward the conductive layers **102** to form a first conductive pattern **120** on an upper surface of the substrate **100** and a second conductive pattern **130** on a bottom surface of the substrate **100**. Through the plated through holes **110**, the first conductive pattern **120** can electrically connect with the second conductive pattern **130**. It should be noted that a plating bar **140** electrically connecting to the first conductive pattern **120** and the second conductive pattern **130** must be simultaneously formed in the step shown in FIG. 1B.

Afterward, as shown in FIG. 1C, a first solder mask (SM) **122** and a second solder mask **132** are formed on the opposing surfaces of the substrate **100** for covering predetermined portions of the two conductive patterns **120** and **130** respectively to define particular connecting positions. Then, as shown in FIG. 1D, a plurality of metal pads **124** and **134** are formed in the openings of the solder masks **122** and **132** by plating. It is noted that the plating bar **140** is utilized for providing negative charges to both the conductive patterns **120** and **130**. Thus, the conductive patterns **120** and **130** become cathodes in the plating process shown in FIG. 1D, which can let metal ions adhered thereon.

However, the existence of the plating bar **140** may sacrifice a significant amount of area size on the substrate **100** for laying the conductive patterns **120** and **130**, and the number of connecting positions on the substrate **100** is thus limited.

On the other hand, an electroless plating technology, which no plating bar **140** is needed, can be used for forming a highly smooth plating surface. However, the electroless plating technology has a primary drawback that poor adhesion is resulted between the plating layer and the plated layer. The metal pads **124** and **134** formed in the process of FIG. 1D need a tightly adhesion toward the conductive patterns **120** and **130** so as to guarantee a reliable signal transmission path. Therefore, the electroless plating technology is not suitable in the present situation.

Moreover, in the plating process of FIG. 1D, the metal pads **124** and **134** are respectively formed simultaneously on the first conductive pattern **120** and the second conductive pattern **130** so that identical material composition and similar thickness can be achieved. However, metal pads **124** and **134** arranged with different pitches on the opposing surfaces of the substrate **100** are preferred in most packaging designs for adapting different connecting means, such as pins and bumps, on the opposing surfaces. For example, in a typical flip-chip packaging, the metal pads **124** on the upper surface of the substrate **100** are used to connect to a die with high density arrayed pads through the bumps, and the metal pads **134** on the bottom surface are used to connect to a main board by using pins, bumps, or other conducting means. The pitch of the metal pads **124** on the upper surface is thus smaller than that of the metal pads **134** on the bottom surface.

For the electroless plating technology is not suitable for plating metal pads **124** and **134** onto the conductive patterns **120** and **130**, an additional plating bar **140** is thus required for providing negative charges to the conductive patterns **120** and **130**. In addition, the plated metal pads with identical material composition and similar thickness may limit the adaptability of such packaging substrate.

SUMMARY OF THE INVENTION

Accordingly, the present invention provides a fabrication method having a plating step without using a plating bar so as to have the area on the packaging substrate less occupied, and also to increase the number of connecting positions on the packaging substrate.

The present invention also provides a fabrication method allowing different connecting means formed on the opposing surfaces of the packaging substrate, so that arrangement regarding the packaging can be versatile.

A fabrication method of a packaging substrate introduced in the present invention including: providing a substrate with a first conductive pattern formed on an upper surface thereof and a second conductive pattern electrically connecting to the first conductive pattern formed on a bottom surface thereof; then forming a first solder mask on the upper surface to define first connecting positions on the first conductive pattern and a second solder mask on the bottom surface to define second connecting positions on the second conductive pattern; forming a seed layer on the bottom surface and electrically connecting to the second conductive pattern; forming a passivation layer on a surface of the seed layer; and connecting a cathode to the seed layer for plating metal pads covering the exposed first conductive pattern.

A packaging substrate in accordance with the present invention comprises a substrate with a first conductive pattern formed on an upper surface thereof and a second conductive pattern electrically connecting to the first conductive pattern formed on a bottom surface thereof; a first solder mask, formed on the upper surface to cover part of a first conductive pattern and thus define first connecting positions on the first conductive pattern for connecting to a die; a second solder mask, formed on the bottom surface to cover part of a second conductive pattern and define second connecting positions on the second conductive pattern for connecting to a main board; and a plurality of metal pads formed in the openings of the first solder mask to connecting to the first conductive pattern by plating without using a plating bar.

Reference will now be made in detail to the preferred embodiments of the present invention, examples of which

are illustrated in the accompanying drawings. Wherever possible, the same reference numbers will be used throughout the drawings to refer to the same or like parts.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will now be specified with reference to its preferred embodiment illustrated in the drawings, in which:

FIGS. 1A to 1D depict schematic cross-section views of a fabrication method of a packaging substrate for flip-chip packaging;

FIGS. 2A to 2I depict a sequence of schematic views to show a first preferred embodiment of a fabrication method of a packaging substrate in accordance with the present invention;

FIGS. 3A to 3I depict a sequence of schematic views to show a second preferred embodiment of a fabrication method of a packaging substrate in accordance with the present invention; and

FIGS. 4A to 4E depict a sequence of schematic views to show a third preferred embodiment of a fabrication method of a packaging substrate in accordance with the present invention following the step shown in FIG. 2C.

DETAIL DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIGS. 2A to 2I depict a sequence of schematic views to show a first preferred embodiment of a fabrication method of a packaging substrate in accordance with the present invention. Firstly, as shown in FIG. 2A, a substrate 200 is provided with through holes 210 formed by mechanical or laser drilling. Afterward, the substrate 200 and the through holes 210 are plated with a conductive material to form conductive layers 202 on the opposing surfaces of the substrate 200. Also as shown, the conductive layers 202 are connected electrically with the plated through holes (or blind via, not shown in figures) 210.

Then, as shown in FIG. 2B, a lithographic and etching process is carried out toward the conductive layers 202 to result a first conductive pattern 220 on an upper surface of the substrate 200 and a second conductive pattern 230 on a bottom surface of the substrate 200. The first conductive pattern 220 is communicated electrically with the second conductive pattern 230 through the plated through holes (or blind via, not shown in figures) 210, and thus a basic circuit board is therefore resulted.

Afterward, as shown in FIG. 2C, a first solder mask (SM) 222 is formed on the upper surface of the substrate 200 to define a predetermined number of first connecting positions on the first conductive pattern 220, and a second solder mask 232 is formed on the bottom surface of the substrate 200 to define another predetermined number of second connecting positions on the second conductive pattern 230.

Then, as shown in FIG. 2D, an organic surface preservative (OSP) layer 234 is formed in the openings of the second solder mask 232 to cover the exposed surfaces of the second conductive pattern 230. The OSP layer 234 is specifically utilized to prevent the composition, such as copper, of the conductive pattern 230 from being thermally oxidized. Afterward, as shown in FIG. 2E, solder layers 236 are filled into the openings of the second solder mask 232, and the OSP layer 234 (FIG. 2D) is vaporized simultaneously by the heat. It is noted that the existence of the OSP layer 234 helps to prevent the formation of surface oxides between the solder layer 236 and the conductive pattern 230 so as to

guarantee a reliable adhesion between the solder layers 236 and the conductive pattern 230.

Then, an electroless deposition process such as physical vapor deposition process, is carried out without any preceding lithographic steps to form a seed layer 240 on the exposed surfaces of the second solder mask 232 and the solder layers 236. The deposited seed layer 240, which is usually composed of copper, has a preferred thickness less than 1 micron. Afterward, as shown in FIG. 1G, a passivation layer 250 is formed on the surface of the seed layer 240.

It is noted that the seed layer 240 builds a current transmission path from an edge of the substrate 200 toward the solder layers 236. The solder layers 236 are electrically connected to the second conductive pattern 230, and the second conductive pattern 230 is further electrically connected to the first conductive pattern 220 through the plated through holes (or blind via, not shown in figures) 210. Therefore, in the plating process shown in FIG. 2H, by connecting a cathode to the seed layer 240, the exposed surfaces of the first conductive pattern 220 may segregate negative charges to attract positive metal ions adhering thereon to form metal pads 224 covering the exposed first conductive pattern 220. Finally, as shown in FIG. 2I, the unwanted passivation layer 250 and the seed layer 240 are removed to expose the solder layers 236 on the bottom surface of the substrate 200 to finish the packaging substrate.

As shown in FIG. 2I, the packaging substrate formed by the above mentioned fabrication process has the substrate 200, the first conductive pattern 220, the second conductive pattern 230, the first solder mask 222, the second solder mask 232, a plurality of solder layers 236, and a plurality of metal pads 224. The first conductive pattern 220 is formed on the upper surface of the substrate 200, and the second conductive pattern 230 electrically connecting to the first conductive pattern 220 is formed on the bottom surface of the substrate 200.

The first solder mask 222 is formed on the first conductive pattern 220 and the upper surface of the substrate 200, and covers part of the first conductive pattern 220 to define the first connecting positions on the first conductive pattern 220 for connecting to a die. The second solder mask 232 is formed on the bottom surface of the second conductive pattern 230 and the substrate 200, and covers part of the second conductive pattern 230 to define the second connecting positions on the second conductive pattern 230 for connecting to a main board. The solder layers 236 fill the openings of the second solder mask 232 and connect to the second conductive pattern 230. The metal pads 224 are formed in the openings of the first solder mask 222 to connect to the exposed first conductive pattern 220 by plating without using plating bar.

It is noted that the resulted packaging substrate has some metal pads 224 on the upper surface thereof and some solder layers 236 on the bottom surface thereof. The material composition and the thickness of the metal pads 224, the OSP layer 234, and the solder layers 236 may be adjusted individually. For example, the metal pads 224 in the present embodiment, which is formed right above the conductive pattern 220, may be specifically chosen as a gold/nickel plated layer to prevent the formation of some unwanted inter-metallic compositions. Moreover, the metal pads 224 formed on the upper surface of the substrate 200 are utilized for connecting the die pads, which usually needs a higher arrayed density. Therefore, the pitch of the metal pads 224 on the upper surface of the substrate 200 is much smaller than that of the solder layers 236 on the bottom surface thereof.

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FIGS. 3A to 3I depict a sequence of schematic views to show a second preferred embodiment of a fabrication method of a packaging substrate in accordance with the present invention. Firstly, as shown in FIG. 3A, a substrate **300** is provided with plated through holes **310** formed therein, and two conductive layers **302** connecting to the plated through holes **310** are formed on the opposing surfaces of the substrate **300**. Then, as shown in FIG. 3B, a lithographic and etching process is carried out toward the conductive layers **302** to result a first conductive pattern **320** on an upper surface of the substrate **300** and a second conductive pattern **330** on a bottom surface of the substrate **300**.

Afterward, as shown in FIG. 3C, isolation layers **321** and **331** are under coated into the openings of the conductive pattern **320** and **330** to prevent ion migration event resulting short circuit or open circuit. Then, a first solder mask **322** is formed on the upper surface of the substrate **300** for covering part of the conductive pattern **320** and the isolation layer **321** so as to define first connecting positions on the first conductive pattern **320**, and also a second solder mask **332** is formed on the bottom surface of the substrate **300** for covering part of the conductive pattern **330** and the isolation layer **331** so as to define second connecting positions on the second conductive pattern **330**.

Then, as shown in FIG. 3D, an OSP layer **334** is formed in the openings of the second solder mask **332** to prevent the oxidation of the second conductive pattern **330**. Afterward, as shown in FIG. 3E, solder layers **336** are filled into the openings of the second solder mask **332**, and the OSP layer **334** is vaporized simultaneously by the heat. Afterward, as shown in FIG. 3F, a seed layer **340** is formed on the exposed surfaces of the second solder mask **332** and the solder layers **336**. Then, as shown in FIG. 3G, a passivation film **350** is formed on a bottom surface of the seed layer **340**.

The seed layer **340** builds a current transmission path from an edge of the substrate **300** toward the solder layers **336**. Therefore, in the plating process shown in FIG. 3H, by connecting a cathode to the seed layer **340**, the exposed surfaces of the first conductive pattern **320** may segregate negative charges to attract positive metal ions adhered thereon to form metal pads **324** covering the exposed first conductive pattern **320**. Finally, as shown in FIG. 3I, the unwanted passivation layer **350** and the seed layer **340** are removed to expose the solder layers **336** on the bottom surface of the substrate **300** to finish the packaging substrate.

FIGS. 4A to 4D depict a sequence of schematic views to show a third preferred embodiment of a fabrication method of a packaging substrate in accordance with the present invention following the step shown in FIG. 2C. As shown in FIG. 4A, a seed layer **440** is formed on a bottom surface of the second solder mask **232** and the second conductive pattern **230**. Then, as shown in FIG. 4B, an OSP layer **434** is formed on a bottom surface of the seed layer **440** with respect to the openings of the second solder mask **232**. Afterward, as shown in FIG. 4C, solder layers **436** are formed on the OSP layer **434**, and the OSP layer **434** is vaporized simultaneously by the heat.

Afterward, as shown in FIG. 4D, a passivation layer **450** is formed on a bottom surface of the solder layers **436** and the seed layer **440**. A cathode voltage level is applied through the seed layer **440**, the second conductive pattern **230**, and the plated through hole **210** to the first conductive pattern **220** for plating metal pads **424** on the first conductive pattern **220** through the openings of the first solder mask **222**. Finally, as shown in FIG. 4E, the unwanted passivation

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layer **450** and the seed layer **440** are removed to expose the solder layers **436** to finish the packaging substrate.

Notice that the OSP layer and the solder layers in the foregoing described embodiments could be omitted in the present invention. (Not shown in figure). Taking the third embodiment as an example. If there has no OSP layer **434** and solder layers **436** on the bottom surface, the passivation layer is formed directly over seed layer **440**. Accordingly, removing passivation layer **450** and seed layer **440** would result exposed Cu pad. In this case, the OSP layer will be applied on the exposed Cu pad as surface finish.

A substrate without solder layer **436** would have better reliability when using lead-free solder balls in the following mounting process.

By contrast to the prior art packaging substrate, the packaging substrate in accordance with the present invention and the fabrication method thereof has the following advantages:

1. As shown in FIG. 1B, the traditional plating process is carried out with a plating bar **140** for applying a cathode voltage level to the conductive patterns **120** and **130**. However, a seed layer **240** shown in FIG. 2H in accordance with the present invention is able to build a current transmission path for applying the cathode voltage level to the conductive pattern **220**. Upon such an arrangement, the plating bar **140** in the prior art is no more needed. Therefore, the area available for laying conductive patterns may be increased to allocate more connecting points on the packaging substrate, and also possible operation noise caused by the plating bar can be avoided.

2. Although the prior art electroless plating process does not need the plating bar, it has a primary drawback of a poor adhesion resulted between the plating layer and the plated. Whereas, as shown in FIG. 2H, the metal pads **224** are formed by using traditional electro-plating technology to guarantee a tightly adhesion with the conductive patterns **220**.

3. In the prior fabrication method, the metal pads, formed on the upper surface and the bottom surface of the packaging substrate with identical surface plating process, have similar thickness and material composition. However, different connecting means adapted to different connection method and with different arrayed density are preferred for most packaging designs. Thus, as shown in FIG. 2I, the packaging substrate in accordance with the present invention has metal pads **224** typically using gold/nickel plated layers for connecting to the die pad, and solder layers **236** for connecting to the printed circuit board with or without pins or balls. In addition, the thickness of the metal pads **224** formed by electroplating may be controlled with high precision. Consequently, the packaging substrate in accordance with the present invention is suitable to various packaging, with different connecting means, and also has a potential to reduce the fabrication cost.

With the example and explanations above, the features and spirits of the invention will be hopefully well described. Those skilled in the art will readily observe that numerous modifications and alterations of the device may be made when retaining the teaching of the invention. Accordingly, the above disclosure should be construed as limited only by the metes and bounds of the appended claims.

What is claimed is:

1. A fabrication method of a packaging substrate comprising the steps of:
 - forming a first conductive pattern on an upper surface of a substrate and forming a second conductive pattern on

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a bottom surface of the substrate, wherein the second
 conductive pattern is electrically connected to the first
 conductive pattern;

forming a first solder mask on the upper surface of the
 substrate to define first connecting positions on the first
 conductive pattern and forming a second solder mask
 on the bottom surface to define second connecting
 positions on the second conductive pattern;

forming a seed layer on the bottom surface of the sub-
 strate, the seed layer is electrically connected to the
 second conductive pattern;

forming a passivation layer on a surface of the seed layer;
 and

connecting a cathode to the seed layer for plating metal
 pads covering the exposed first conductive pattern.

2. The fabrication method of claim 1, further comprises
 under-coating isolation layers in the openings of the first
 conductive pattern before forming the first solder mask.

3. The fabrication method of claim 1, further comprises
 under-coating isolation layers in the openings of the second
 conductive pattern before forming the second solder mask.

4. The fabrication method of claim 1, further comprises
 filling solder layers in the openings of the second solder
 mask before forming the seed layer.

5. The fabrication method of claim 4, further comprises
 forming an organic surface preservation (OSP) layer in the
 openings of the second solder mask before filling solder
 layers in the openings of the second solder mask.

6. The fabrication method of claim 1, further comprises
 filling solder layers in the openings of the second solder
 mask after forming the seed layer.

7. The fabrication method of claim 6, further comprising
 forming an OSP layer in the openings of the second solder
 mask before filling solder layers in the openings of the
 second solder mask.

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8. The fabrication method of claim 1, further comprises
 removing the passivation layer and the exposed portions of
 the seed layer after forming metal pads on the exposed first
 conductive pattern.

9. A fabrication method of packaging substrate compris-
 ing the steps of:

forming a first solder mask on an upper surface of a circuit
 board to define first connecting positions thereon and
 forming a second solder mask on a bottom surface of
 the circuit board to define second connecting positions
 thereon;

forming a seed layer on the second solder mask;

forming a passivation layer on a bottom surface of the
 seed layer;

connecting a cathode to the seed layer for plating metal
 pads on an exposed conductive pattern;

removing the passivation layer; and

removing the seed layer.

10. The fabrication method of claim 9, further comprises
 filling solder layers in the openings of the second solder
 mask before forming the seed layer.

11. The fabrication method of claim 10, further comprises
 forming an OSP layer in the openings of the second solder
 mask before filling solder layers in the openings of the
 second solder mask, and the OSP layer is vaporized in the
 step of filling the solder layers in the openings of the second
 solder mask.

12. The fabrication method of claim 9, further comprises
 forming an OSP layer after removing the passivation layer
 and the seed layer.

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